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Distributed Virtual Synchronous Generator approach versus Singular Virtual Synchronous Generator approach: A dynamic stability evaluation

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Abstract
This paper reports the modeling and dynamic performance of a wind penetrated multi-area power system incorporating a Singular Virtual Synchronous Generator (SVSG)/Distributed Virtual Synchronous Generator (DVSG). The active and reactive power controls are achieved by using Superconducting Magnetic Energy Storage (SMES) as Virtual Synchronous Generator (VSG). SMES based VSG control parameters are tuned offline using genetic algorithm (GA). Two topologies of VSGs are considered in this paper: SVSG at lowest inertia generator bus (SVSGGENBUS), SVSG at load bus (SVSGLOADBUS) and DVSG of comparatively smaller rating at three lowest inertia generator buses. A modified 18 machine, 70-bus power system is simulated in MATLAB/Simulink environment. System performance is assessed for two different types of disturbances: step wind disturbance and three-phase fault. The simulation results show that rate of change of frequency (ROCOF), deviations in frequency and voltage are minimized with DVSG. Transient stability measured in terms of critical clearing time (CCT) verifies that CCT is increased by DVSG topology.

Keywords
Virtual Synchronous Generator, Superconducting Magnetic Energy Storage, frequency, faults, wind disturbance, critical clearing time

Introduction

The large-scale integration of renewable energy sources (RESs) such as wind, solar, geothermal, and biomass to power systems has become unavoidable due to two universally recognized challenges: the dependency on fossil-fuel and the need to reduce environmental impact of massive increase in energy. China has an installed capacity of 221 GW and is the leader in wind energy followed by USA with 96.4 GW. In other countries like Germany, India and Spain significant amount of power from renewable energy sources is planned to be connected to their power systems upto next two decades.

In conventional power plants, the alternators provide inertia to the grid through their rotating parts. This inertia helps to regulate grid frequency by avoiding frequency deviation from the regular frequency operation. But, these power plants are responsible for greenhouse gas emissions. To reduce the greenhouse emissions, integration of RESs is encouraged. However, these RESs have either small or no rotating part. Therefore, they reduce the inertia of the grid dramatically leading to frequency/voltage instability as compared to the system using sysnchronous generators (Aouini et al., 2014; Bevrani et al., 2014; Hartmann et al., 2019). The CCT reduces because of

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